SPIROMETRY UPDATE

Navy Environmental Health Center

Chesapeake, VA

Objectives

- Identify indications for spirometry testing in the occupational health setting.
- Describe how to apply 1994 ATS Spirometry Standards to pulmonary function testing to assure high-quality results.
- Describe the major types of spirometers, spirometer performance criteria, validation steps, and daily spirometry calibration checks to standardize procedures and equipment for participants use.

Objectives

- Describe the appropriate techniques for performing the spirometry maneuvers.
- Identify the acceptability of the volume-time curves.
- Describe the quality control and infection control measures to assure accurate spirometry results.
- Recognize the importance of good quality spirometry for appropriate provider decision making.

ATS 1994 Update

- Areas pertinent to occupational pulmonary function testing
  - Critical role of technician in obtaining accurate results.
  - Recommended changes in testing procedure.
  - Equipment validation.
  - Quality control
  - Infection control and hygiene concerns

Indications

- Primary prevention
  - Pre-placement and fitness-for-duty examinations
    - Physical demands of a job (heavy manual labor, fire fighting);
    - Characteristics of respiratory use (prolonged use of negative-pressure mask under conditions of heavy physical exertion and/or heat stress - not required by OSHA);
    - Research and monitoring of health status in groups of workers.

Indications

- Secondary prevention
  - Medical surveillance programs – workers at risk of developing occupationally related respiratory disorders
    - Baseline and periodic evaluations
    - Mandated OSHA regulations (asbestos, cadmium, coke oven emissions or cotton dust)
    - Local mandated medical surveillance program
    - Component of workplace health promotion program

Indications

- Tertiary prevention
  - Clinical evaluation of symptomatic individuals
    - Restrictive
    - Obstructive
    - Combined ventilatory defects
  - Disability under Social Security Administration
  - Federal Coal Mine Health and Safety Act
  - Workers' compensation setting

Navy NIOSH Approved Spirometry Courses

- Navy Environmental Health Center Course Directors
  - Betty J. Applegate, RN, COHN-S
    - Naval Hospital, Lemoore California
      - bapplegate@bmclem.med.navy.mil
  - Anita E. Steckel, RN, COHN-S
    - Navy Environmental and Preventive Medicine Unit Six, Pearl Habor Hawaii
      - steckel@nepmu6.med.navy.mil

Navy NIOSH Approved Spirometry Courses

- Naval Hospital Bremerton Course Director
  - Anita Sadler, RN, COHN-S
    - sadlera@pnw.med.navy.mil
- NEHC Homepage for course list.
  - www-nehc.med.navy.mil

References

- Standardization of Spirometry: 1994 Update. Am J Resp Crit Care Med 152: 1107-1136 1995. (3rd ATS Official Statement on Spirometry)
- Lung Function Testing: Selection of Reference Values and Interpretative Strategies. Am Rev Resp Dis 144: 1202-1218, 1991
- Respiratory Protection Guidelines. Am J Resp Crit Care Med 154: 1153-1165, 1996

References

- Guidelines for Evaluation of Impairment/Disability in Patients with Asthma. Am Rev Resp Dis 147: 1056-1061, 1993. (May download from http://www.thoracic.org)
- Secondary to Respiratory Disorders. Am Rev Resp Dis 133: 1205-1209, Evaluation of Impairment Disability, 1986. (Second ATS Official Statement on Evaluation of Impairment Due to Respiratory Disorders.)
- ACOEM Position Statement on “Spirometry in the Occupational Setting.” (May download from http://www.acoem.org

References

- ACOEM Position Statement on “Evaluating Pulmonary Function Change Over Time in the Occupational Setting” dtd 02 Feb 2004.
- Spirometric Reference Values from a Sample of the General U.S. Population. Am J Respir Crit Care Med, Vol 159, pp 179-187, 1999

Pretest for Spirometry Update

1. The FEV1 is:

   a. The volume of air exhaled during the last second of expiration.
   b. The final exhaled volume of air at one minute.
   c. The volume of air forcibly exhaled during the first second of expiration.
   d. The volume of air inspired during the first second.

2. The FVC is:

   a. The maximum amount of air that can be exhaled after the fullest inhalation possible.
   b. The volume of air inhaled and exhaled during quiet, normal breathing.
   c. The maximum volume of air which can be exhaled forcefully after maximal inspiration.
   d. The amount of air remaining in the lungs after a complete exhalation.

3. The Forced Expiratory Volume in One Second (FEV1) as a percent of Forced Vital Capacity (FVC) is calculated by using:

   a. The largest FEV1 and FVC from the same curve.
   b. The largest FEV! And FVC from any of the curves even if the curves are not valid.
   c. The largest FEV1 and FVC, even if they are not from the same curve.
   d. The best FEV1 and FVC from the same curve.

4. The current American Thoracic Society Standards (ATS) states that a plateau in the volume-time curve is reached when:

   a. There is less than 25 ml volume change in 2.0 seconds.
   b. There is less than 25 ml volume change in 0.5 second.
   c. There is less than 30 ml volume change in 1.0 second.
   d. There is less than 30 ml volume change in 0.5 second.

5. In calculating excessive variability for the FVC and the FEV1, the volume between the top two curves (tracings) are examined to see that they are:

   a. 5% or 100 ml (whichever is greater).
   b. 10% or 100 ml (whichever is greater).
   c. Less than 0.2 liters or 200 ml.
   d. Greater than 0.2 liters or 200 ml.

a. 2.90 to 3.10
b. There is no standardized calibration range.
c. 2.91 to 3.09
d. 2.88 to 3.12

7. The extrapolated volume is the volume exhaled before the timing of the maneuver has started. All of t
are true except for:

a. The extrapolated volume should not be greater than 10% of the FVC or 150 ml, whichever number is
b. Excessive extrapolated volume is a type of hesitation or false start.
c. The extrapolated volume should not be greater than 5% of the FVC or 150 ml, whichever number is g
d. The extrapolated volume is used to determine whether or not the tracing is acceptable to use for ca

8. With regards to the predicted "normal" values in non-Caucasian subjects, especially African-Americans,
the following statements is correct?

a. The FEV1 and FVC is the same in Caucasians and non-Caucasians.
b. The FEV1/FVC Ratio is 15% less in non-Caucasian subjects.
c. The FEV1 and FVC are 15% less in non-Caucasian subjects.
d. Race correction is not required in the OSHA Cotton Dust Standard.

9. A 28 year-old man who has worked as a firefighter for the past 4 years is found to have an FVC of 5.62 l
previous FVC was 5.85 liters. What is the absolute change and percent of change in his FVC from the p

a. Absolute change is .023 liters and percent of change is 0.4%.
b. Absolute change is .23 liters and percent of change is 3.9%.
c. Absolute change shows a loss of .23 liters and percent of change shows a loss of 3.9%
d. Absolute change shows a loss of .023 liters and a percent of change shows a loss of 0.4%.

10. A spirogram has three acceptable tracings. The curves had the following FEV1s: A=2.96 liters, B=2.86
C=3.18 liters. What is the excessive variability between the two largest FEV1s?

a. .16 liters or 160 ml.
b. .32 liters or 320 ml
c. .22 liters or 220 ml
d. .31 liters or 318 ml

Spirometry Parameters

Navy Environmental Health Center

Chesapeake, VA

Spirometry Parameters

- Forced Vital Capacity
  - FVC
- Forced Expiratory Volume in One Second
  - FEV1
- Forced Expiratory Volume in One Second Expressed as a Percentage of the Forced Vital Capacity
  - FEV1/FVC %
- Mean Forced Expiratory Flow during the Middle Half of the Forced Vital Capacity
  - FEF 25-75%

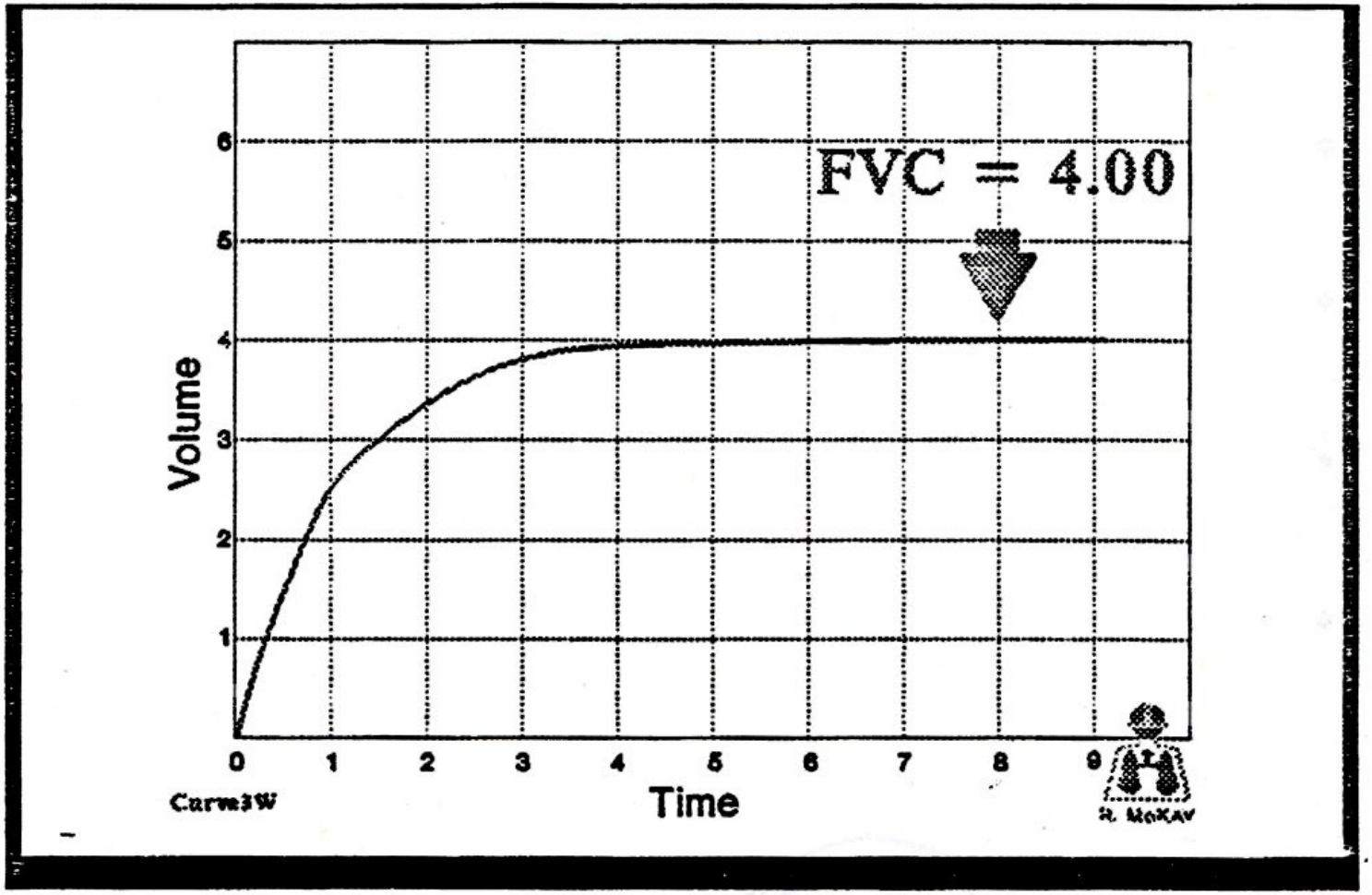
FVC

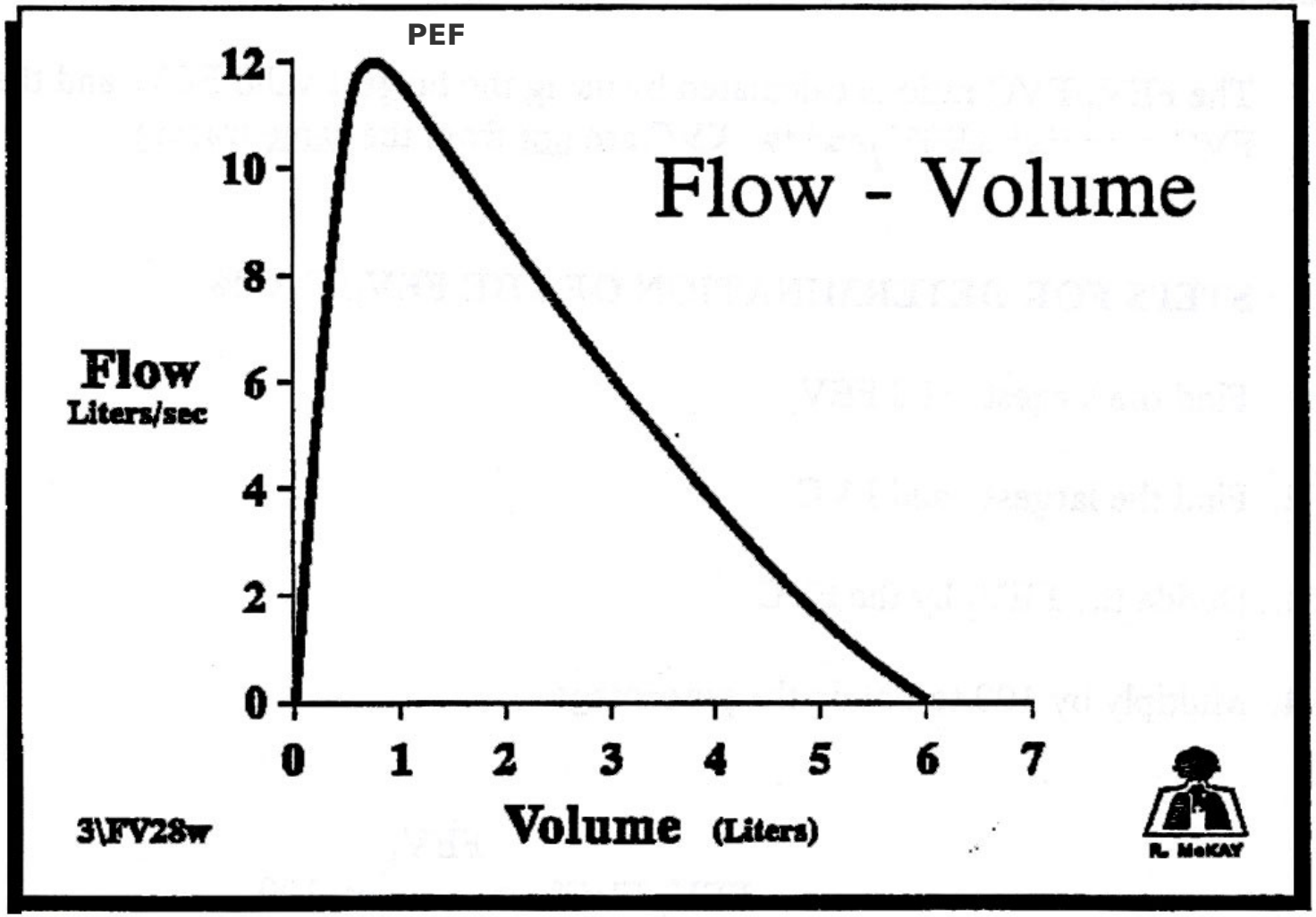
- Definition:
  - Defined as the maximal amount of air that can be exhaled **forcefully** after a maximal inspiration or the most air a person can blow out after taking the deepest possible breath.

FVC

- End of Test Criteria
  - The volume time curve show an obvious plateau
    - Plateau defined as no change in volume for at least one second.
    - Subject cannot or should not continue further exhalation.
    - The forced expiration is of reasonable duration.

FVC




PEF
Flow - Volume
Flow
Liters/sec
12
10
8
6
4
2
0
0 1 2 3 4 5 6 7
Volume (Liters)
3\FV28w
R. McKAY

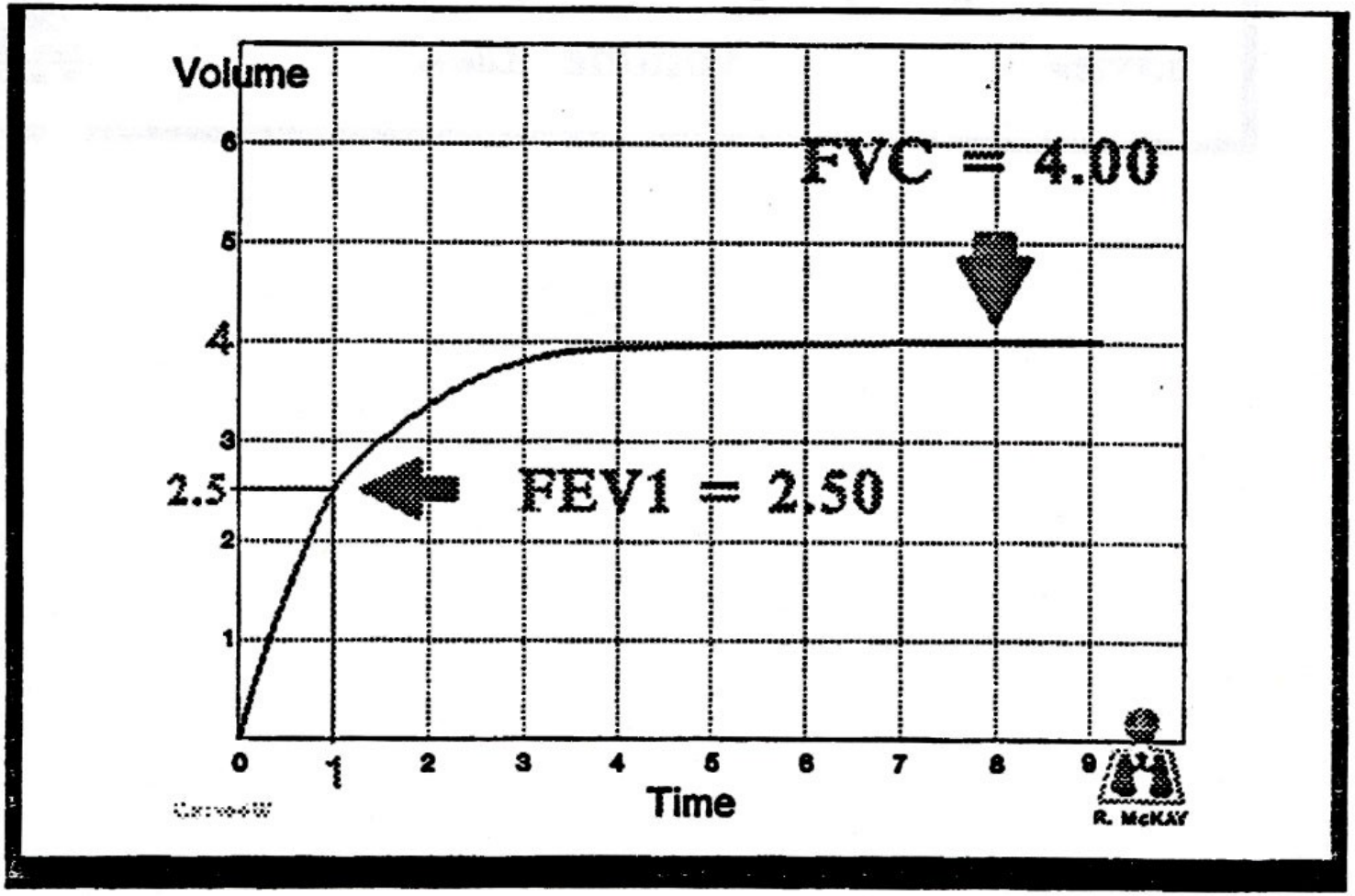
FEV1

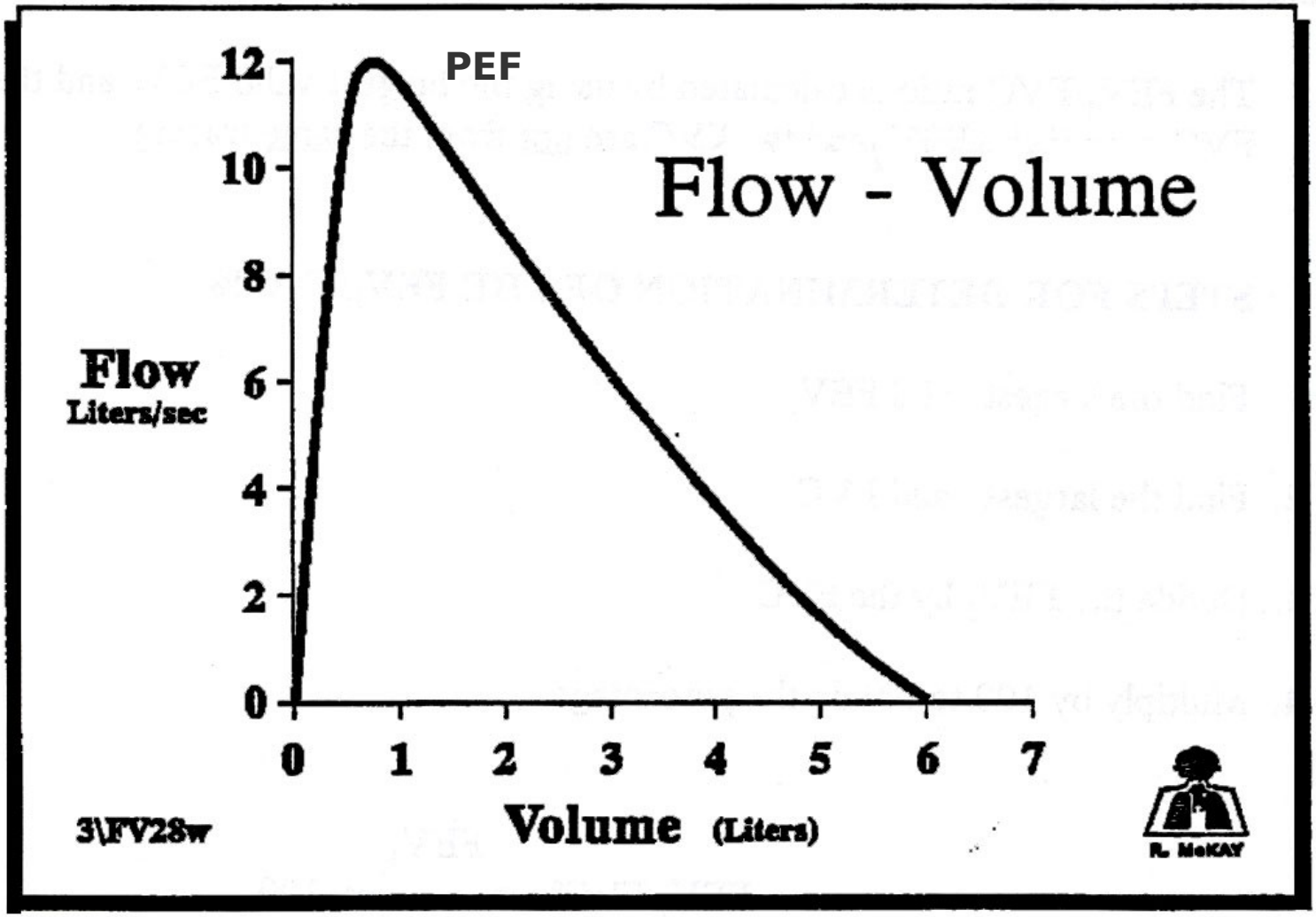
- Definition:
  - The volume of air exhaled during the first second of a **forced** expiratory maneuver.

FEV1

- Steps for determination of the FEV1:
  - Determine **Time Zero** using the back extrapolation technique;
  - Measure over one second from **Time Zero**;
  - Draw a straight line up from the point where Time = one second and the point where the straight line intersects is the FEV1.

FEV_1




PEF
Flow - Volume
Flow
Liters/sec
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
Volume (Liters)
3\FV28w
R. McKAY

FEV1/FVC%

- Definition:
  - The value expresses the volume of air the worker exhales in one second as a percent of the total volume of air that is exhaled.
  - Calculated by using **largest** valid FEV1 and **largest** FVC even if they are not from the same tracing.
    - Find largest valid FEV1
    - Find largest valid FVC
    - Divide FEV1 by FVC
    - Multiply by 100 to obtain percentage.

FEF25-75%

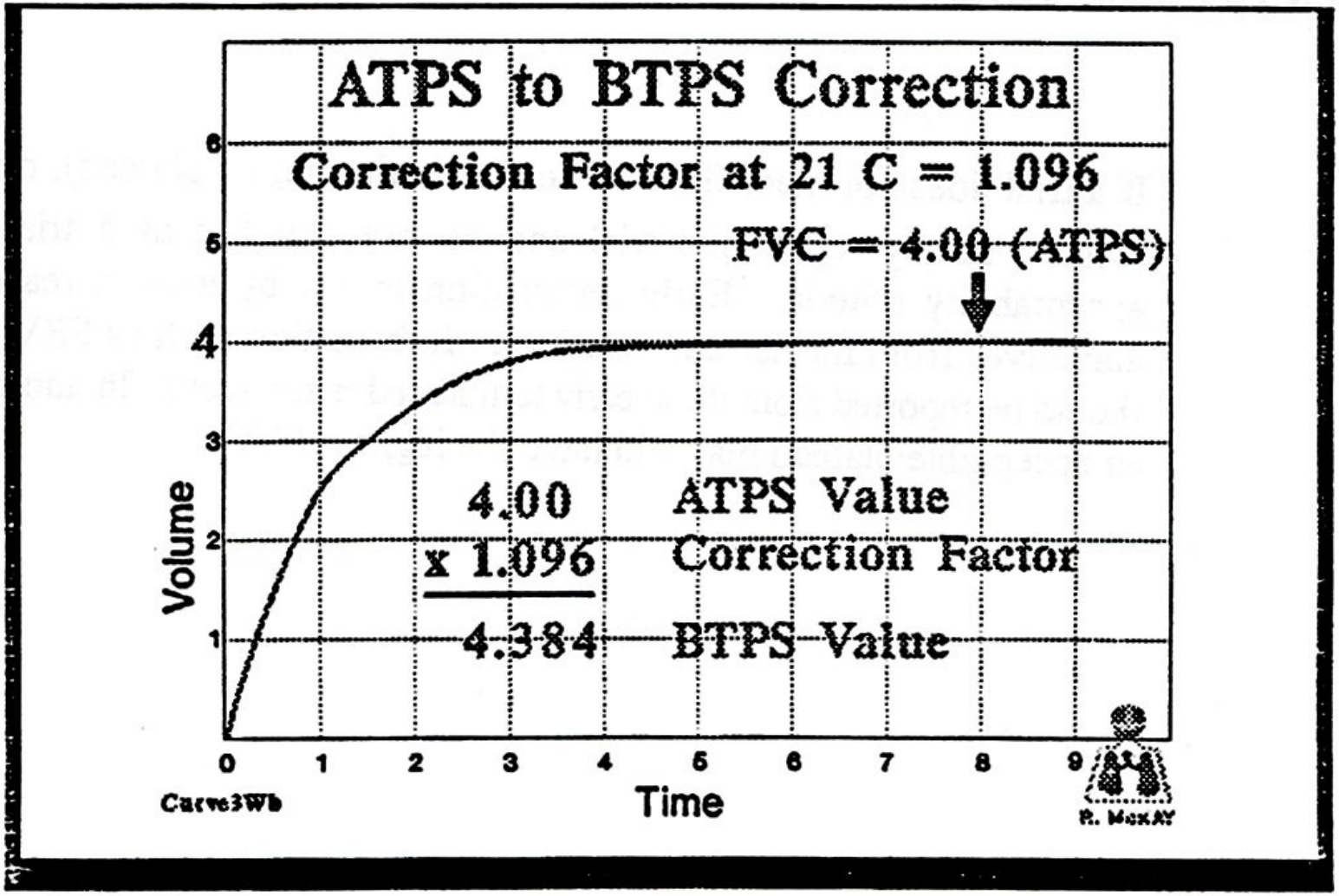
- Definition:
  - The mean expiratory flow during the middle half of the FVC
    - More sensitive than FEV1.
    - Considerably more variability than FVC and FEV1.
    - ATS recommends only be considered after determining presence and clinical severity of impairment and should not be used to diagnosis disease in individual patients

BTPS

- Definition:
  - Gas (air) at:
    - Body Temperature (37°C)
    - Ambient Pressure (surrounding air pressure)
    - Saturated with water vapor (relative humidity = 100% as is the case in the lungs)

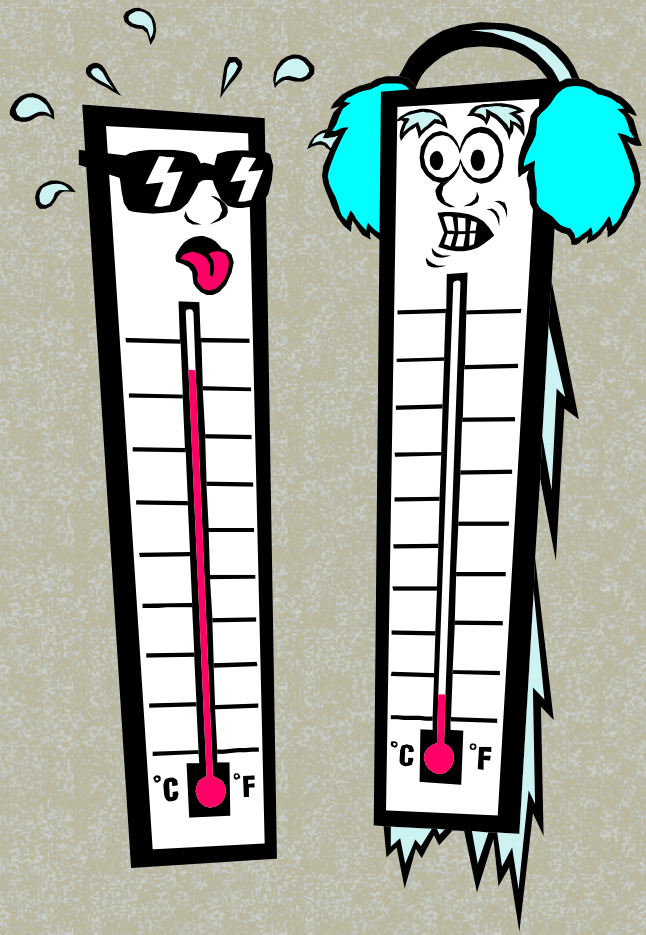
BTPS

- Spirometric test requiring conversion to BTPS
  - FEV1, FVC, and FEF25-75% all represent **volume** (volume per unit of time) – must be converted to BTPS.
  - FEV1/FVC% is ratio of volumes – **does not** have to be converted.


ATPS to BTPS Correction
Correction Factor at 21 C = 1.096
FVC = 4.00 (ATPS)
4.00 ATPS Value
x 1.096 Correction Factor
4.384 BTPS Value
Volume
Time
0 1 2 3 4 5 6 7 8 9
1 2 3 4 5 6
Carve3Wb
R. McKAY

BTPS

- Points to remember:
  - Temperature
    - Ambient temperatures should be recorded to within 1°C.
    - Spirometric testing should only be done with ambient temperatures between 17° - 40°C.



Reproducibility (Variability)

- ATS recommends obtaining three (3) valid tracings with reproducible FVC's and FEV1.
  - The two largest valid FVC's are examined to determine there is no more than a .2 liter (200 ml) difference between them.
  - The two largest valid FEV1 are examined to determine there is no more than a .2 liter (200 ml) difference between them.

Variability

- Calculating excessive variability for FVC
  - To find if the difference is greater than 200 ml.

Best FVC – Second Best FVC =

Optional: 1987 ATS states 5% or 100 ml (whichever is great). If the difference is greater than 100 ml, then percentage criterion should be used. If the difference is not greater than 100 ml there is **no** excessive variability.

.

Variability

- Calculating Excessive Variability for FEV1 or FVC:
  - To find if the difference is excessive in percentage (OPTIONAL):

$$\%\ \text{Reproducibility} = \frac{\text{Best FVC} - \text{Second Best FVC}}{\text{Best FVC}} \times 100$$

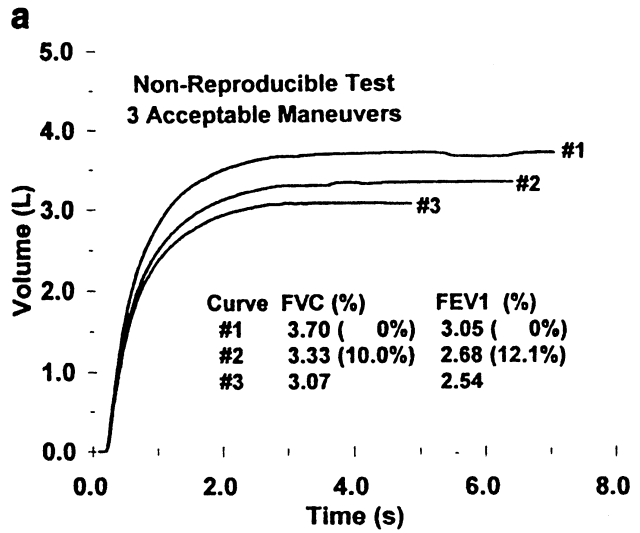


Figure A7a. Nonreproducible test with three acceptable volume–time curves. Percents are difference from largest value.

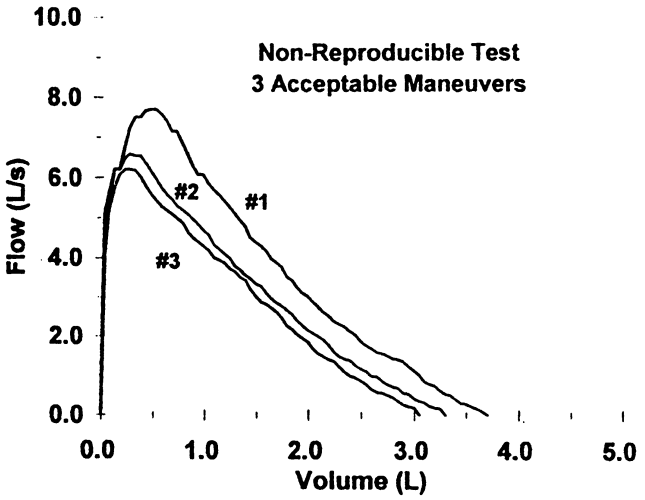


Figure A7b. Nonreproducible test with three acceptable flow–volume curves.

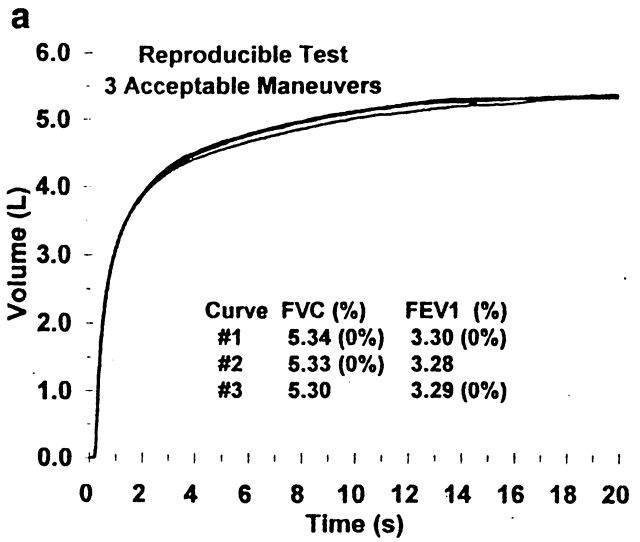


Figure A8a. Reproducible test with three acceptable volume–time curves. Percents are difference from largest value.

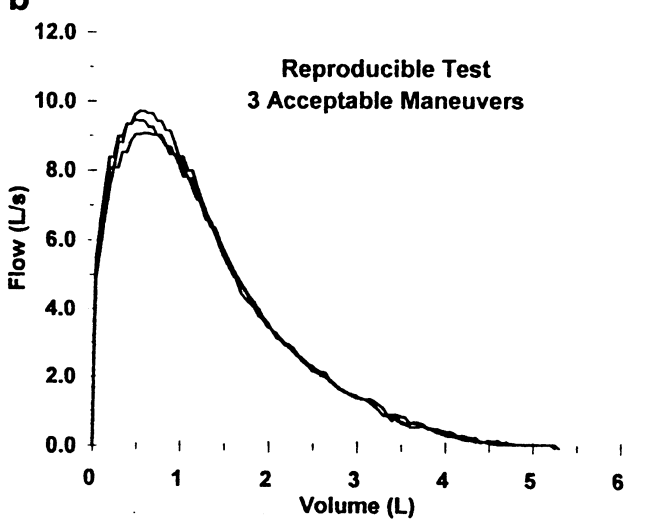
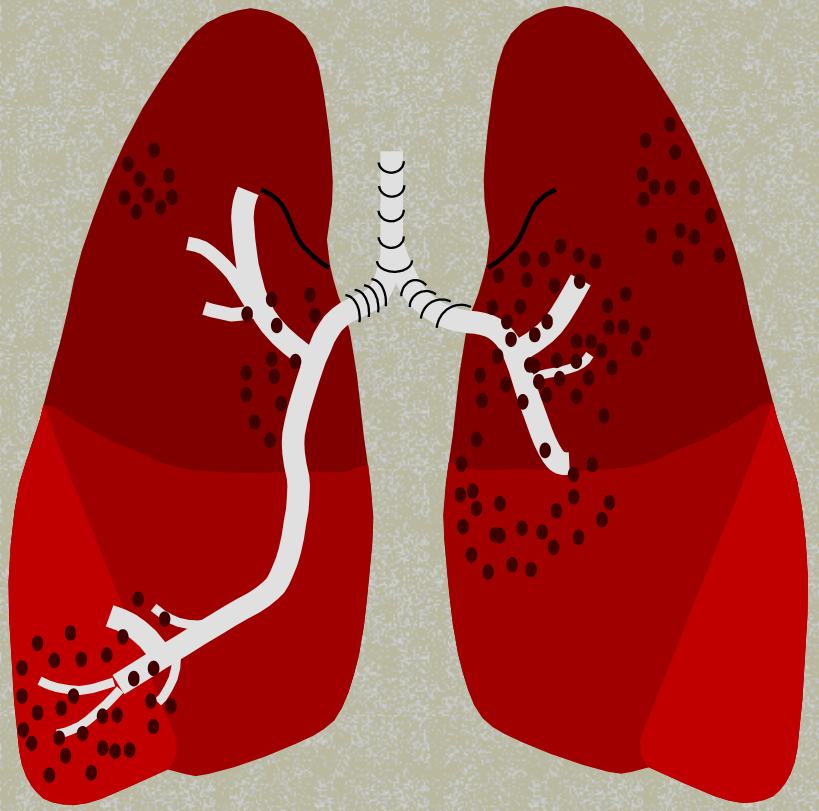


Figure A8b. Reproducible test with three acceptable flow–volume curves.

Points to Remember

- FVC
  - Convert answer to BTPS when needed.
- FEV1
  - Excessive variability and extrapolated volume must be calculated to determine if additional maneuvers are needed.
  - Convert to BTPS when needed.
- FEV1 and FVC
  - Always use largest volume from an acceptable tracing to ensure maximal results.



Performance Maneuvers

Navy Environmental Health Center

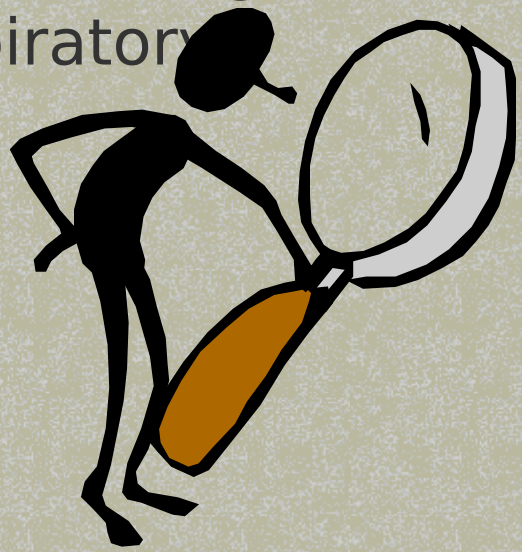
Chesapeake, VA

Performance

- Subject Instruction and Maneuver Performance
  - Recommendations:
    - Technicians should demonstrate appropriate technique.
    - Imperative to have a complete inhalation before subject **“blasts”** the air out.
    - Enthusiastically coach subject.
    - Observe subject and chart recorder during test to better ensure maximal effort.

Performance

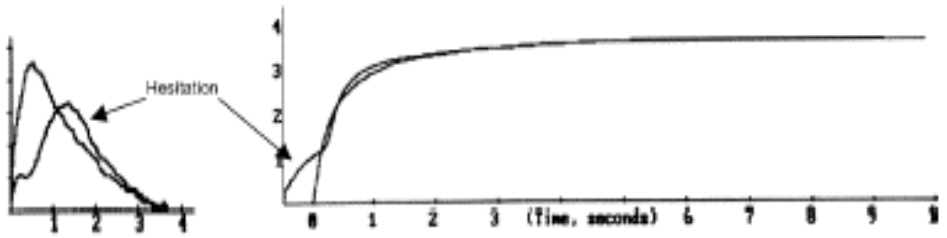
- Recommendations
  - Perform a minimum of three acceptable FVC maneuvers.
  - May require up to eight maneuvers be performed if subject shows large variability between expiratory maneuvers.



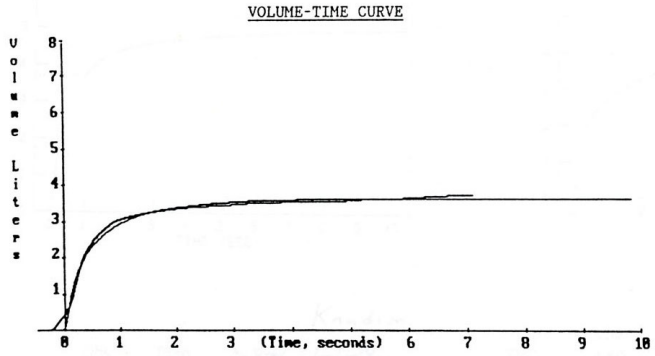
Performance

- Start-of-Test Criteria
  - Recommendation:
    - To achieve accurate “time zero”, the FEV1 must come from a maximal effort curve.
    - Extrapolated volume must be less than 5% of the FVC or 0.15 liter, whichever is greater.

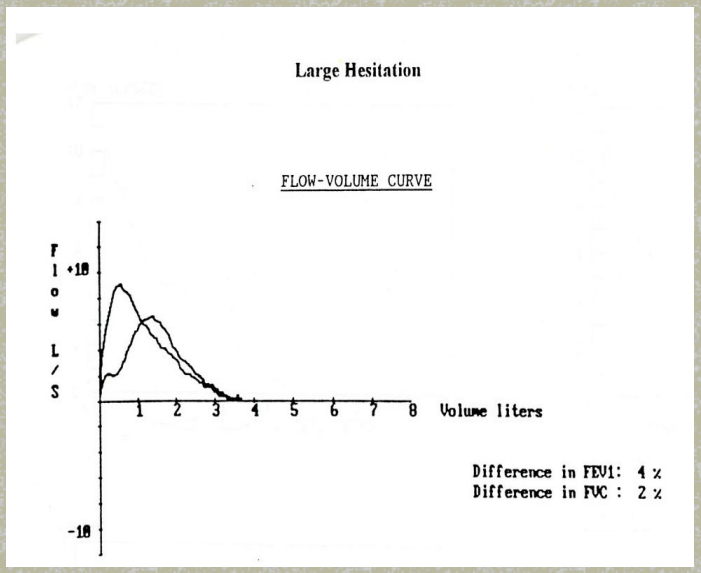
Figure 3: Excessive Hesitation



	FEV1	% Pred	FEV1/FVC5	% Pred
Good Effort	3.23	109	82	101
Large Hesitation	3.34	112	83	102

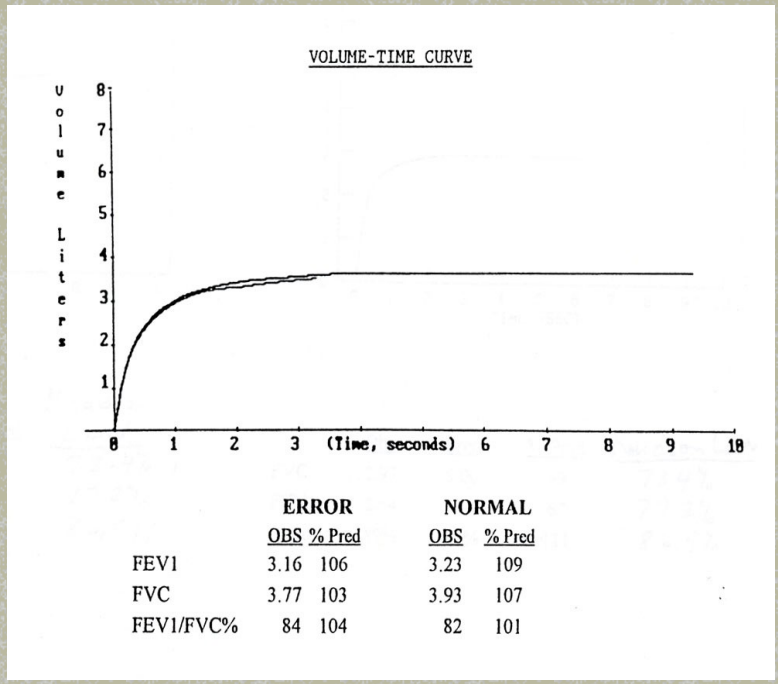


	ERROR		NORMAL	
	OBS	% Pred	OBS	% Pred
FEV1	3.34	112	3.23	109
FVC	3.11	85	3.93	107
FEV1/FVC%	80	99	82	101

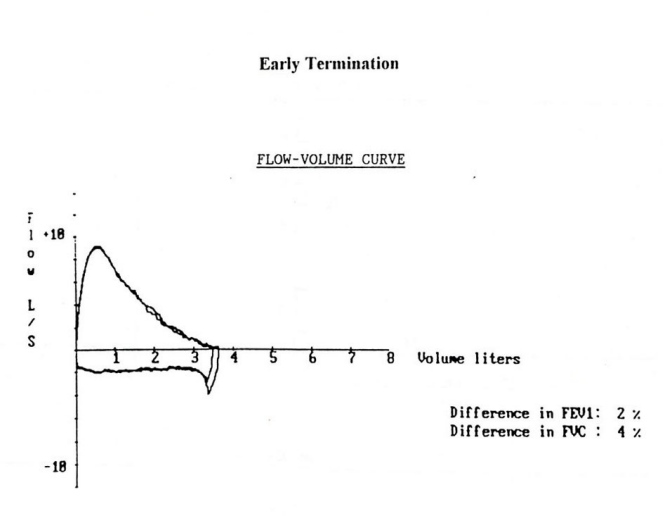


Performance

- Minimum exhalation time
  - Minimum exhalation time of 6 seconds (length of maximum expiratory effort).



	ERROR		NORMAL	
	OBS	% Pred	OBS	% Pred
FEV1	3.16	106	3.23	109
FVC	3.77	103	3.93	107
FEV1/FVC%	84	104	82	101



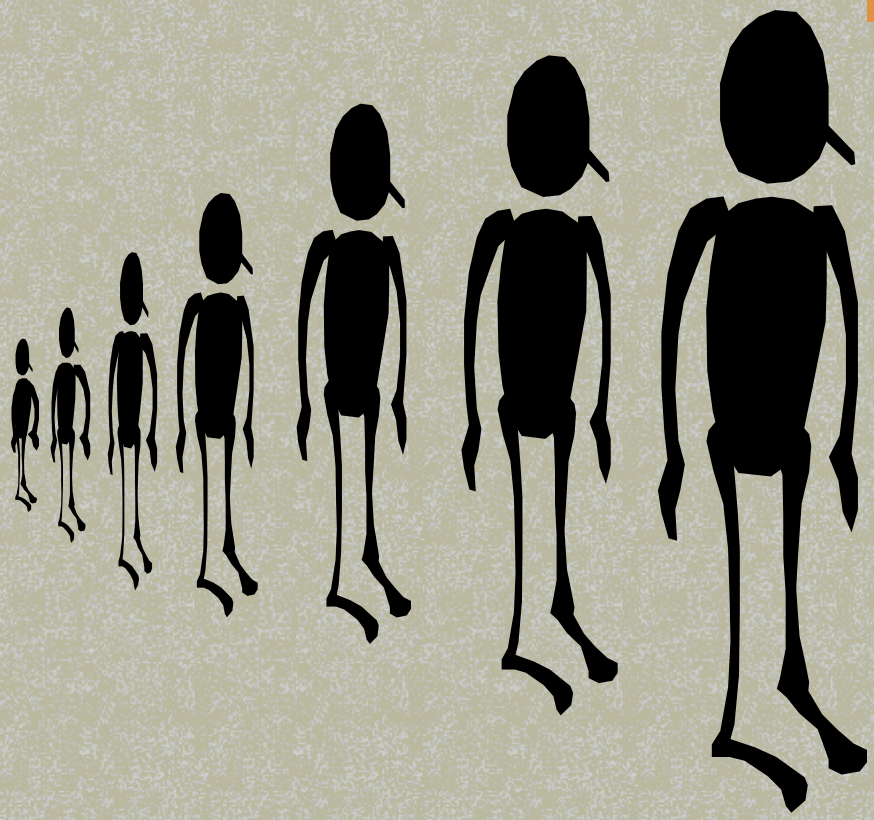
Performance

- End of Test Criteria
  - Subject cannot or should not continue further exhalation.
  - Volume-time curve show an obvious plateau.
    - To meet ATS criteria, the minimal detectable volume for spirometers must be 30 ml or less for at least one second.

Performance

- End of test criteria
  - Forced exhalation is of reasonable duration
    - Multiple prolonged exhalations.
      - May cause light headedness, undue fatigue, and unnecessary discomfort.
      - Exhalations greater than 15 second rarely change medical decisions.

Performance



- Maximum number of maneuvers.
  - Eight maneuvers is considered a practical upper limit for most subjects.

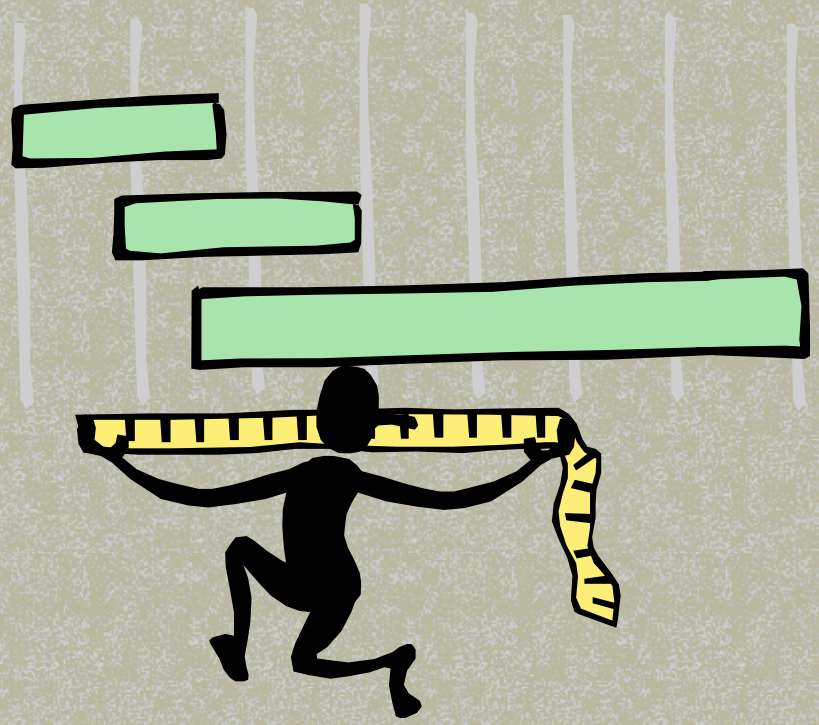
Performance

- Environmental conditions
  - Ambient temperature must always be recorded and reported to an accuracy of ± 1° C.
    - 17° C is judged to be acceptable and reasonable lower limit.
      - Some subjects may develop airflow limitations with the inhalation of very cold air.

Performance

- Use of nose clips
  - Recommendation:
    - Nose clips are not required when doing open circuit technique; however some people breathe through the nose and use of nose clips is encouraged.
- Sitting vs. Standing
  - Recommendation:
    - Testing may be done either in the sitting or standing position; indication of position is necessary on the report.

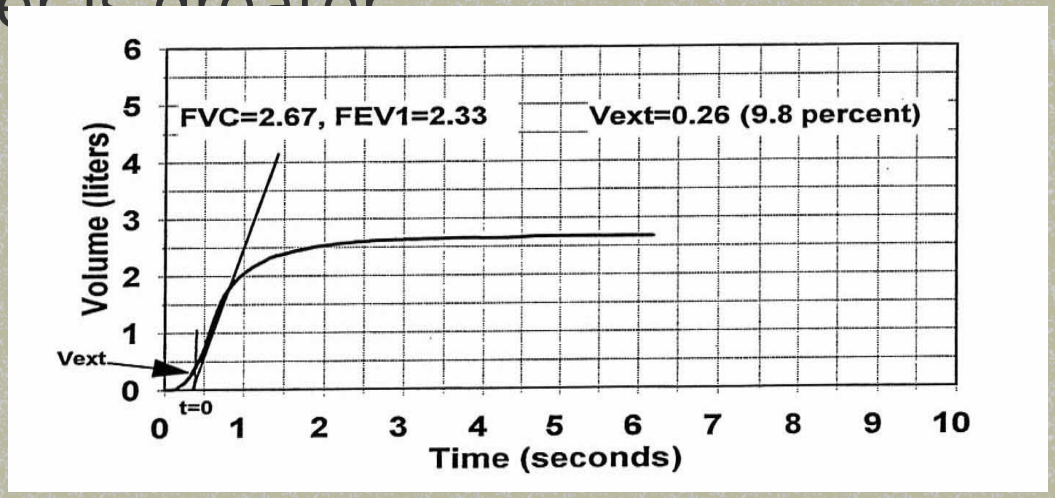
Performance



- Measurement
  - Recommendation:
    - Largest FVC and FEV1 should be recorded after examining data from all the acceptable curves, even if they do not come from the same curve.

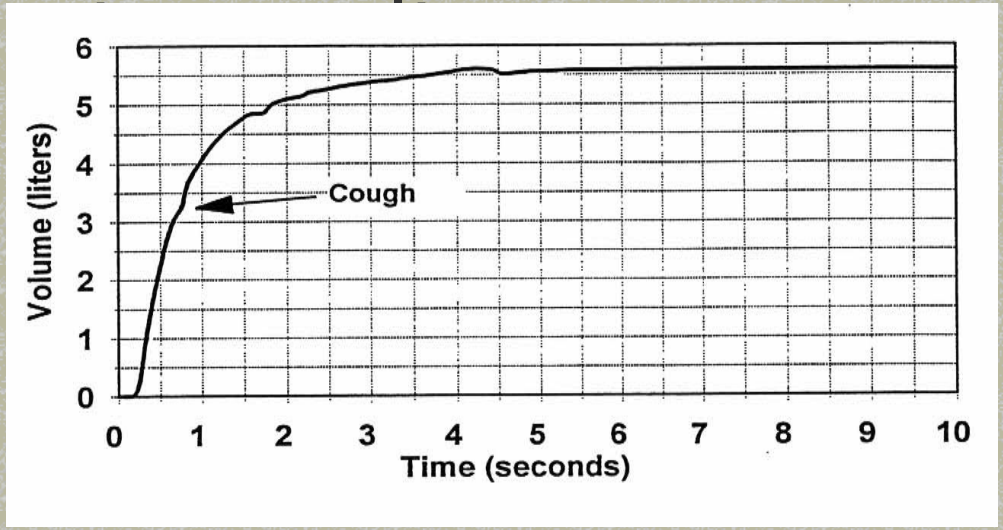
Performance

- Maneuver acceptability
  - Technician must perform test without:
    - An unsatisfactory start of expiration – characterized by extrapolated volume of greater than 5% of FVC or 0.15 L, whichever is greater



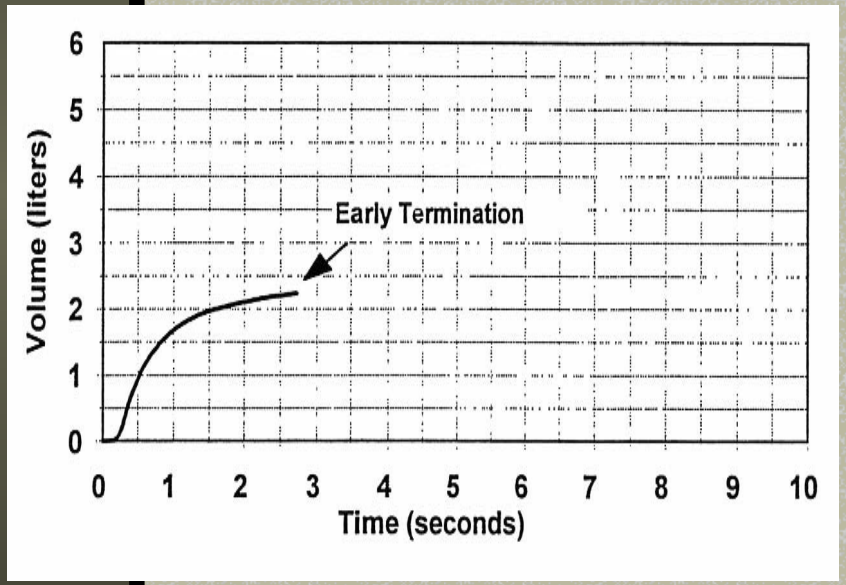
Performance

- Coughing during the first second of maneuver, or any cough in the technician's judgment that interferes with measurement of accu

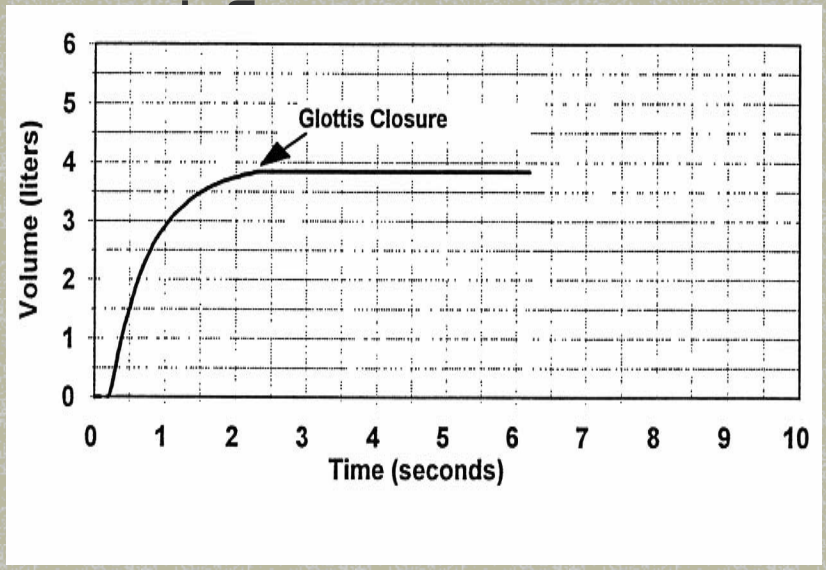


Performance

- Early termination of expiration.

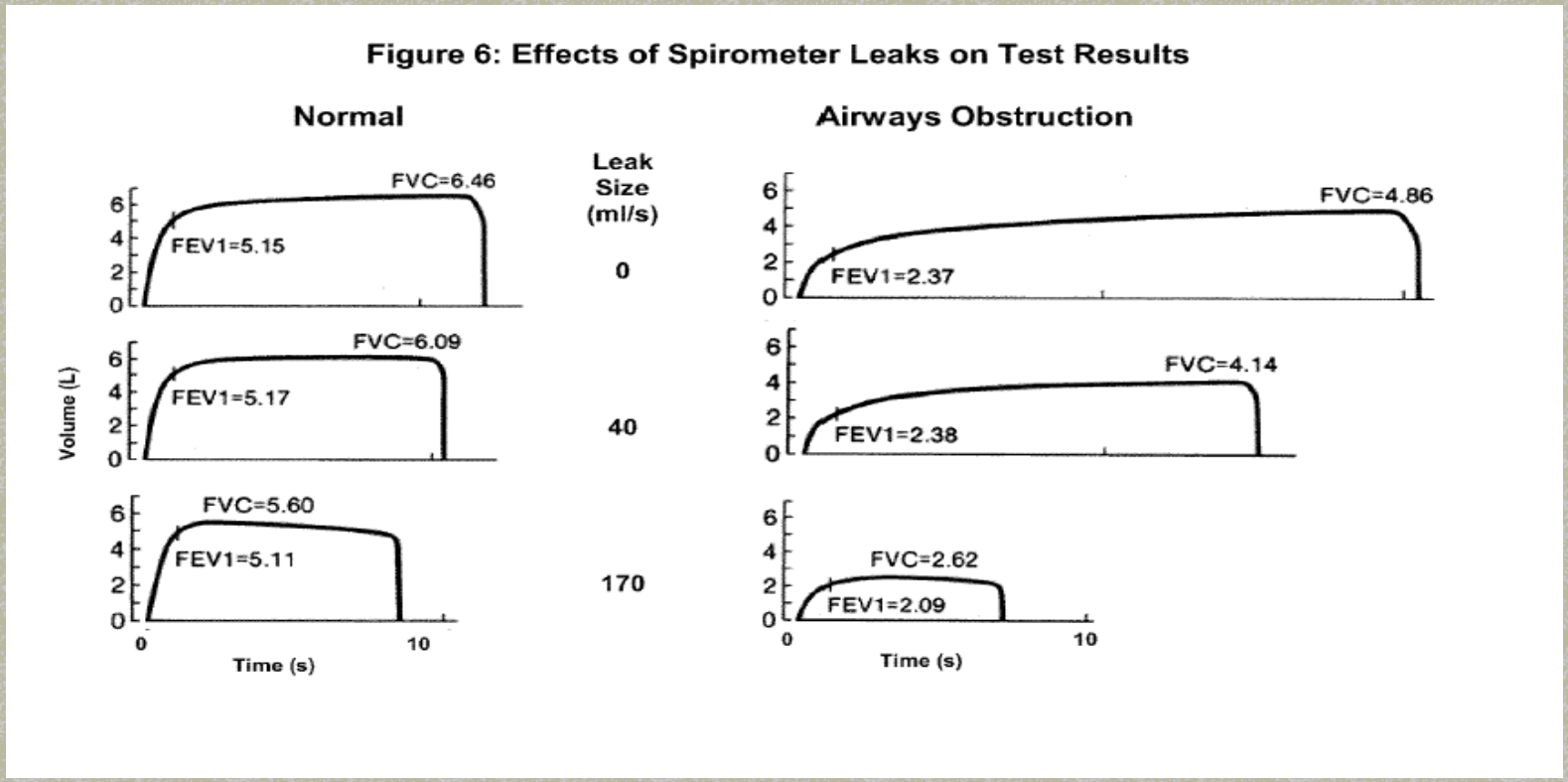


- Valsalva maneuver (glottis closure) or hesitation during the maneuver that causes a cessation of



Performance

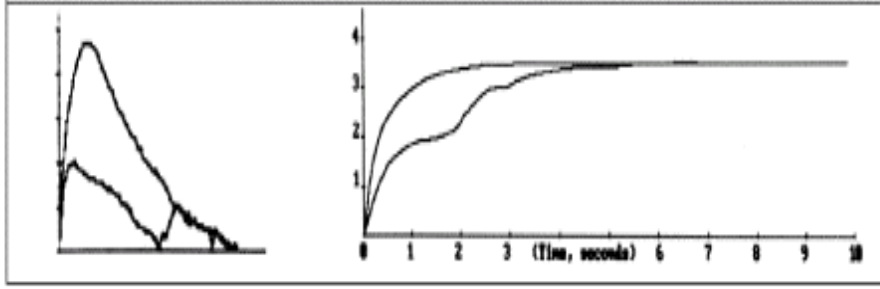
- Leaks



Performance

- An obstructed mouthpiece (obstruction due to the tongue being placed in front of the mouthpiece or false teeth falling in front of the mouth piece).

Figure 7-4. TONGUE IN MOUTHPIECE



Parameter	Observed	% Pred
FVC (L)	3.85	105
FEV1 (L)	2.02	68
FEV1/FVC, %	52	64

Performance

- Test result reproducibility
  - The largest FVC and second largest FVC from acceptable maneuvers must not vary by more than 0.2 Liter (200 ml).
  - The largest FEV1 and second largest FEV1 from acceptable maneuvers must not vary by more than 0.2 Liter (200 ml).

Summary

- Acceptability and Reproducibility Criteria:
  - Acceptability criteria
    - Individual spirograms are “acceptable” if:
      - Are free from artifacts
        - Cough or glottis closure during the first second of exhalation
        - Early termination or cutoff
        - Variable effort
        - Leaks
        - Obstructed mouthpiece

Summary

- Have a good start.
  - Extrapolated volume less than 5% of FVC or 0.15 L, whichever is greater
- Have a satisfactory exhalation.
  - 6 second of exhalation and/or a plateau in the volume-time curve; or
  - Reasonable duration or a plateau in the volume-time curve; or
  - If the subject cannot or should not continue to exhale.

Summary

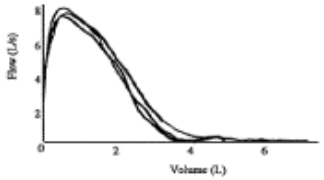
- Reproducibility criteria
  - After three (3) acceptable curves obtained:
    - Are two largest FVCs within 0.2 L of each other?
    - Are two largest FEV1s within 0.2 L of each other?

- If **YES** to both, may conclude test session. Otherwise, continue testing until:

    - Both criteria are met after additional curves are recorded; or
    - A total of eight tests have been performed; or
    - The subject cannot or should not continue.

    - **At a minimum, save the three best maneuvers.**

Figure 4: Zero Flow Error: Screen Pneumotach



57 yo 68" WM	Obs	Pred	%Pred
Best FVC (L)	7.48	3.67	204%
Best FEV1 (L)	3.52	2.89	122%
FEV1/FVC (%)	47.1	78.8	60%
FVC Reprod = 2.50 L		FEV1 Reprod = 0.19 L	

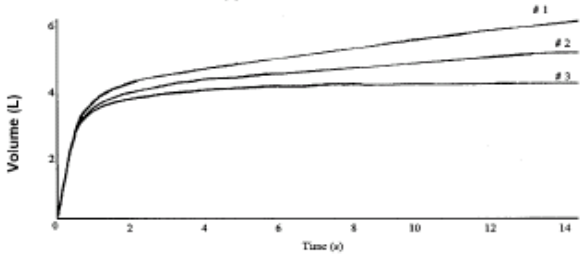
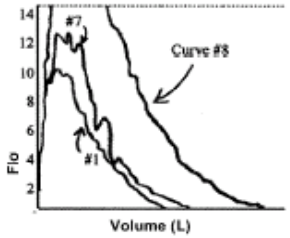


Figure 5: Condensation/ Mucus Deposition: Screen Pneumotach



46 yr 72" WM	Obs	Pred	%Pred
Best FVC (L)	7.59	5.28	144%
Best FEV1 (L)	5.82	4.30	135%
Best PEF (L/s)	15.9	9.59	166%
FEV1/FVC %	76.7	81.1	95%
FVC Reprod	2.29 L		
FEV1 Reprod	1.95 L		
PEF Reprod	3.91 L (25%)		

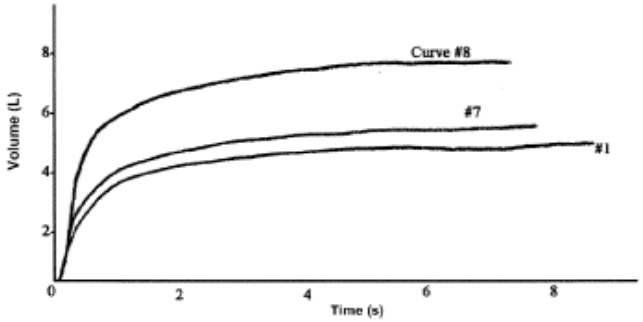


Figure 6: Effects of Spirometer Leaks on Test Results